Egyptian Journal of Geology, v. 64, 2020, p. 471-484

TAPHONOMIC CONDITIONS AND ASSESSMENT OF THE LATE CRETACEOUS VERTEBRATES BEARING SITES IN THE WESTERN DESERT, EGYPT

Gebely A. Abu El-Kheir,

New Valley University, faculty of science, geology department, Kharga, 72511,
gebely2006@scinv.au.edu.eg

ABSTRACT

The detailed stratigraphical field relations and taphonomic conditions and assessment of the Upper Cretaceous vertebrate bearing horizons in Western Desert of Egypt were investigated in the three sites; Campanian Quseir Formation, Kharga Oases, Maastrichtian Ammonite Hill member of Dakhla Shale, Abu Minqar and Lower Cenomanian Bahariya Formation in Gebel El Dist, Bahariya Oases. It was found that the most important taphonomic factors controlling the preservation state of vertebrate fossils in the selected sites are rate of transportation and sedimentation as well as bio-erosion and diagenetic events of the bearing sediments. A comparative study of these factors was achieved between the investigated vertebrates bearing sites. The study indicated that the vertebrate fossils in Bahariya and Kharga Oases are more preserved and less abraded than these in Abu Minqararea. Generally, the study vertebrate fossils that yielded in sandstones have better preserved state than other lithological types. Furthermore, the deposition in low rate of transportation and high rate of sedimentation give the vertebrate carcasses good opportunity for the rapid burying with articulated and semi articulated elements, consequently better preservation state. Due to the importance of the vertebrate bearing low topographic sites in the Western Desert, its highly recommended to carry out serious and decisive mitigation for the protection against negative impacts that caused by human activities (e.g. illegal land reclamation and ecotourism) which leading to groundwater rise in these lowlands.

Keywords: Late Cretaceous, vertebrate fossil horizons, taphonomy, Kharga, Abu Minqar, Bahariya.

INTRODUCTION

The Western Desert of Egypt is considered one of the most important localities in the world, contains many natural heritage sites, in addition to the most attractive landscapes and ecotourism sites containing vertebrate fossils. Despite the very important fossils of the Cretaceous deposits of the Western Desert, a great shortage of knowledge of habitat of the Mesozoic era of Egypt as well as in Africa.

Some localities, containing very interested remnants of Late Cretaceous reptiles are recorded in the Western Desert of Egypt, represented in Cenomanian deposits of Bahariya oasis (Smith et al. 2006), Campanian deposits of Kharga and Dakhla oases (Rauhut and Werner, 1997, Sallam et al. 2016 and Abu AbdelGawad et al. 2019) and Maastrichtian deposits in the western restricted margin of Dakhla basin near Ammonite Hill (Rauhut and Werner, 1997, Abu El-Kheir et al. 2018), (Fig. 1).

These sites yielded many terrestrial and marine Cretaceous reptiles, such as Therapod and Sauropod dinosaurs, land and marine turtles, Crocodiloforms, Mosasour and Pleisosaur remnants, in addition to the reptile bones, the sites produced many species of fish and shark teeth. These discovered reptile fossils contribute in uncovering the mysteries of Mesozoic era life in African continent.

Some reptile remains were discovered in the south of Kharga Oasis such as partial skeletons and separated elements of dinosaurs from the Campanian deposits of Qusier Formation throughout recent expeditions by the New Valley Vertebrate Paleontology center to the south of Kharga Oasis. The authors have uncovered new proof of turtles, crocodiles and dinosaur bones.

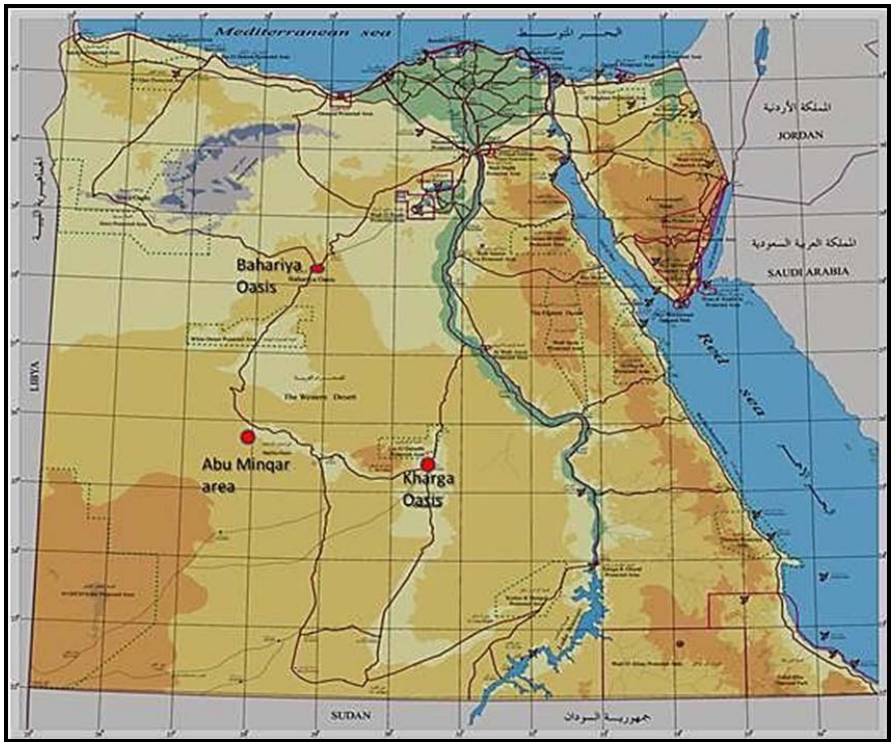

Fig. 1: Map of Egypt, showing the studied vertebrate fossils localities of the Western Desert

The Ammonite Hill member of the lower part of Dakhla Formation, near Abu Minqar village, Farafra Oasis yielded some Mosasour vertebrae, shark teeth, fragmented shells and limb bones of marine turtles and some elements of Maastrichtian dinosaurs, (Lapparent de Broinand Werner,1998 and Abu El-Kheir et al. 2018).

The Bahariya Oasis is the type locality of the early Cenomanian dinosaurs of Egypt. Ernst Stromer (1914) discovered very important dinosaur remnants from Gebel El Dist, Bahariya Formation. These fossils were represented by Therapod and Sauropod dinosaurs. Unfortunately, these fossils were destroyed during an allied bombing raid in Munich during the Second World War, so that, the most published data on these dinosaur fossils were based on the data published by Stromer (1931 and1934).

Smith et al. (2006) discovered partial skeleton of the large Sauropod dinosaur *Paralatitine stromeri* from the tidal flat and tidal channels facies of Bahariya Formation of Bahariya Oasis.

The taphonomic studies concern with the natural factors that affected on the animal immediately after death and the transition from biosphere to lithosphere where the fossilization was conducted (Lyman 1994). The present study discusses the natural geological factors controlling the taphonomic conditions and assessment of the three Cretaceous vertebrate bearing sites in the Western Desert, namely, Kharga Oasis, Abu Minqar area and Bahariya Oasis.

METHODOLOGY

Three distinctive localities, Kharga Oasis, Abu Minqar area and Baharyia Oasis were stratigraphically and paleontologically described. The vertebrate bearing horizons of these localities were detected and described.

According to Boessincker et al. subdivision in 2011 the taphonomic data were recording, including the degree of articulation of the skeleton, degree of fragmentation and degree of abrasion. The degree of the skeleton was classified into three stages, stage (1) articulated, stage (2) disarticulated, stage (3) partial elements and stage (4) isolated elements, and the abrasion was divided into three stages: stage (0) unabraded, stage (1) slightly abraded stage (2) heavily abraded. Fragmentation is divided into three stages: stage (1) unfragmented, stage (2) slightly fragmented and stage (3) highly fragmented.

GEOLOGICAL SETTING

The distinctive Late Cretaceous vertebrate fossils sites in the present work which are represented by Kharga Oasis, Abu Minqar area and Bahariya Oasis are described as follows:

South Kharga Site: New localities of vertebrate fossils are discovered in the south Kharga by the New Valley Vertebrate Paleontology Centre of the New Valley University. These localities bear will distinctive Late Cretaceous reptiles from Qusier Formation, Campanian age.

Quseir Formation has a wide distribution in Kharga and Dakhla in the southwestern Desert and Quseir in Eastern Desert of Egypt. The type section of the Quseir Formation is at Gebel Atshan in Quseir area, Red Sea coast (Youssef 1957). It composed of about 80 m of variegated claystones, siltstone and sandstone intercalations.It extends from the north east to the south west between Kharga-Dakhla oases.It attains 80 m thickness at DakhlaOasis and unconformably underlain by Taref Formation and covered by phosphatic deposits of Duwi Formation (Hendriks,1984, Hermina. 1990, Awad and Abed, 1966).

Quseir Formation is divided into two members; Mut member which is formed of about 30 m of reddish mudstone and fissile shale, overlain by Hindaw member which is formed of about 35 m of variegated shale alternating with glauconitic sandstone and siltstone (Hermina, 1990). These deposits provide intertidal to surpratidal alternate with marsh and estuarine paleo-environment.

In the studied site the Quseir Formation is characterized by the presence of fragmented bones and partially skeletons of the vertebrate fossilsremain as lungfishes, sawfishes, turtle shells, crocodile bones and some separated partial skeletons of dinosaurs.

Abu Minqar area: It is one of the most import sites of the Maastrichtian vertebrate bearings. The vertebrate fossil bearing layers in this area are represented by the Ammonite Hill member (Barthel and Hermann-Degen, 1981) of the lower part of Dakhla Formation, near Abu Minqar village, Farafra, (Tantawy et al. 2001). The Ammonite Hill member is composed of about 40 m of fossiliferous sandstone, siltstone and shale intercalation with high abundance of ammonites, bivalves, gastropods, echinoids, corals, mangrove fossilized fruits and vertebrate remains. The Ammonite Hill member represents the westernmost extending of Dakhla Formation. This member reflects deposition in well-oxygenated shallow waters, nearshore or lagoonal environment, associated with sea-level lowstand periods (Tantawy et al., 2001), of depositional facies characterized by high energy currents and low rate of sedimentation.

Gebel El Dist site: The Cretaceous vertebrate bearing deposits of Bahariya Oasis (in the middle of the Western Desert) represented by Bahariya Formation (Said, 1962), of EarlyCenomanian age, (Stromer, 1934). Bahariya Formation composed of about 170 m thick of fluvio-marine deposits of interbedded cross bedded sandstone, siltstone and glauconitic claystone. These sediments are deposited shelf, subtidal, and fluvial facies (Catuneanu et al. 2006).

Bahariya Formation covers the floor of the Bahariya Oasis, and most of the isolated hills in the Centre of Bahariya Oasis. Its base is unexposed and topped unconformably by the Eocene Limestone or by volcanic eruption in the northern part of the depression. In other places, the Bahariya Formation is overlain by El Heiz Formation with an angular unconformity, and the contact between them is marked by a change in lithology from yellowish grey claystone to a yellowish brown sandy dolostone (Khalifa and Abu El Hassan, 1993 and Catuneanu et al. 2006).

RESULTS AND DISCUSSIONS

The field study and the taphonomic assessments of the three vertebrate bearing localities, Kharga Oasis, Abu Minqar area and Baharyia Oasis are described as follows:

Kharga Oasis vertebrate bearing site

Field investigation

In this site, the Hindawi Memberof Qusier Formation, in the south of Kharga(Fig. 2),expose low angle northeast inclined layers of about 25 m thick and composed of variegated shales and gray glauconitic mudstones and siltstones intercalated with thin layers of ferruginous conglomeratic sandstone, containing

fragments and coprolites (figs. 3A and 3B). The section is topped by about 1 m thick of phosphatic layer, containing shark teeth and fishbones.

The vertebrate fossils are embedded in four successive horizons, forming repeated cycles between the variegated shales and the glauconitic mudstones and the conglomeratic layers. These horizons may be deposited as mixed mud flat paleo-environment.

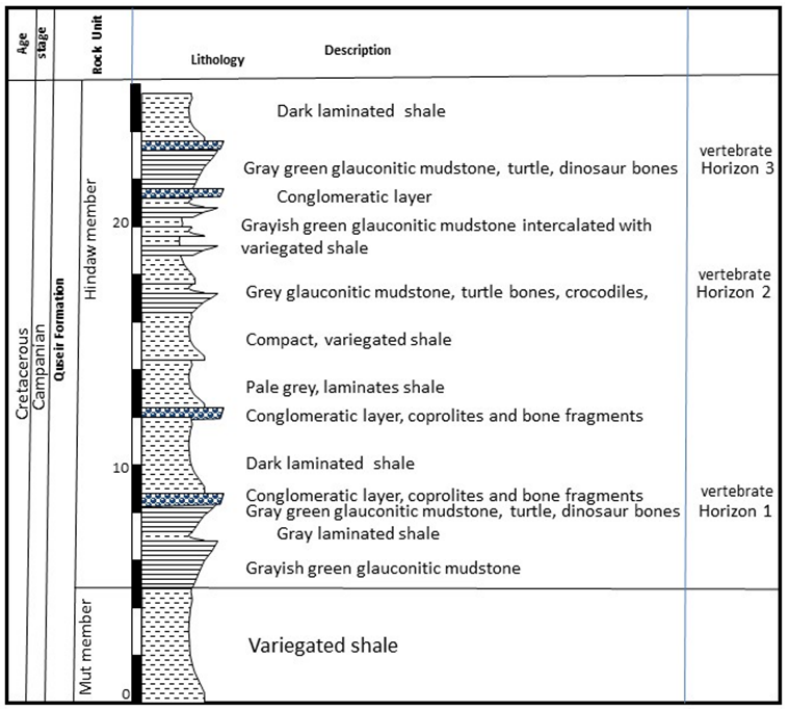

Fig. 2: stratigraphic section of Quseir Formation at the south of Kharga, showing the vertebrate bearing horizons.

The first horizon is detected above the base of the section by about 5 m of the variegated shale. It includes small exposed area to bury beneath the layers due to the general inclining of the layers due to the general inclining of layers toward the northeast. It contains little bone densities of bones. The bones are in the top of the horizon (zone A, of Bossencker, 2011) associated with the conglomerates, coprolites and plant remains. The vertebrate fossils are mainly represented by dinosaur and turtle bones. These bones are heavily abraded, fragmented and highly affected with recent erosion activities.

The second horizon is located above the first horizon by about 8 m, consisting of grayish green, compacted mudstone. It contains fragmented and partial elements of dinosaurs, turtles and some scattered elements of crocodiles. It includes slightly bigger exposure surface than the first exposure but still affected by the general inclining of the strata.

The third horizon is detected above the second horizon by about 6 m and located in the uppermost part of the exposed successions. It is formed of grayish, glauconitic silty mudstone intercalated with tidal channels. The third horizon is the main horizon for the representative vertebrate fossils in south of Kharga Oasis. It contains many scattered elements of sauropod dinosaurs, more than 50 recorded skeletons of turtles and a partial skeleton of crocodile and other scattered elements.

The fourth horizon is lithologically different from the three lower horizons. It is formed of marly phosphatic layer located directly above the third horizon. It contains different species of shark teeth and some bony fish fragments, in addition to some turtle bone fragments.

Fossil contents

Dinosauria

Many separated elements of Sauropod dinosaurs have been recorded from the third horizon such as appendicular elements may refer to sauropod dinosaurs. These elements are represented by isolated ulna,

missing its ends, high weathered tibia, proximal end of radius and slightly well preserved complete humerus, in addition to many fragmented bones of dinosaurs scattered in the horizon, (figs. 3C and 3F)

Testudens

Large numbers of turtle skeletons are recorded in this area. The most of these skeletons are monitored in the vertebrate bearing third horizon. These skeletons are represented by some complete skeletons, separated carapaces and plastrons, beside many fragmented skeletons, highly affected by the recent weathering. Some of the discovered turtle skeletons may be referred to Bothremydidae, (figs. 3D and 3E)

Crocodiloformes

Many scattered elements of the crocodiloformes are collected the site. Few semi complete skulls in well preserved state are collected from the site, in addition to fragmented jaw, and post cranial elements represented by articulated and scattered vertebrae and teeth.

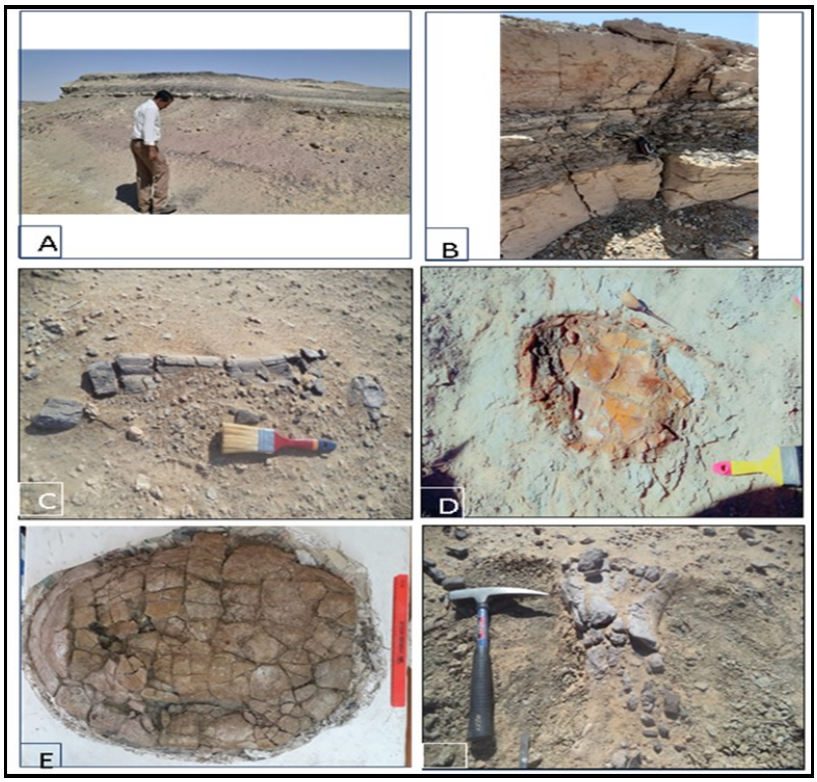

Fig. 3: Vertebrate fossilssite of Kharga Oasis. A) Fragmented element of Saurapod dinosaur, B) variegated shale layers of Quseir Formation, the vertebrate fossils bearing layers, C) Weathered limb element of Sauropod dinosaur, D) Plastron of turtle Skeleton, E) well preserved turtle skeleton. F) Fragmented part of humerus of Sauropod dinosaur.

Taphonomic features

The most of the represented vertebrate fossil bones in the south of Kharga Oasis slightly abraded, fragmented and highly affected by the recent weathering. The bones are embedded in A. zone of the horizon. The turtle fossils in the study area are represented by occasionally complete shells, partial shells and many scattered and weathered turtle shell fragments. Most of the turtle clusters in the site were found disarticulated shells and few of them are associated. Despite the disarticulation of these turtle shells, they are found intact without scattering of the elements, which indicate the disarticulation of the shells were occurred by the erosion after the exposure of the turtle shells (Brand *et al.* 2000). Few complete turtle shells (carapace and plastron association) are collected from the third horizon. Few articulated plastrons are found articulated beneath the fragmented carapace from the same turtle skeleton. Many turtle shells are partially buried in the sediments, as the buried portion is still associated, and the exposed part is disarticulated which support the cause of the disarticulation of turtle shells by erosion process after the sediments were removing above. The turtle shells in the bearing horizons have normal position where the carapace is up and plastron is down, which mains that these turtles were not moved along with the currents. The evidences of predators and bio-erosion are observed on the turtle shells by biting traces of

crocodile teeth and grazing traces on the turtle bones. No turtle skulls are recorded and were only few limb bones are collected from the surface of the fossil bearing layers. These elements may be transported by currents to other sites after the exposure of the turtle skeletons (Brand *et al*. 2000).

More than 50 turtle clusters are recorded in very small area distributed along the detected fossil bearing horizons. This massive concentration of the turtle skeletons may be due their living in small pond and marshes which was suitable habitat for the turtles.

The associated crocodilformes fossils might be lived synchronized with turtles in this pond with very little or without transporting of elements by the currents.

Dinosaur bones were affected by the quiet high energy current of some streams which transported them for short distances into swamp. The high-level underground water has directly erosional effectiveness on the bones by accumulations of iron oxides and alteration by gypsum minerals which ultimately causing cracking and deformation of the bones.

The represented heavy elements such as limb bones with very low abrasion indicate that these bones were transported for short distance, which provide that these animals may have lived at the margin of the pond, where the dense vegetation margins (Mahmoud, 2003).

The presence of shark teeth and fishbones in the phosphatic layer of the fourth horizon may be indicates the southwest transgression of the Tethys sea.

Abu Minqar vertebrate bearing site

Field investigation

The Maastrichtian vertebrate fossils of the Abu Minqar area are observed in Nypa fruits bearing bed (El Hendy et al 2020). This horizon is formed of bioturbated, fossilifeous, calcareous sandstone and siltstone, containing large concentrations of ammonites, Nypa fruits, echinoids, Molusks and vertebrate bones, (Fig. 4). It is partially covered with the eolian deposits and sand dunes. It is extended behind and to the west of Abu Minqar village by separated exposed spots between many isolated hills, where the vertebrate fossils can be collected (Figs 5A and 5 B).

Fossil content

The recording of Maastrichtian vertebrate fossils is very rare in Egypt and generally in Africa. The first discovered Maastrichtian vertebrate fossils of the Western Desert of Egypt were documented by Raughut et al. (1997). These fossils are represented by well-preserved dinosaur sauropod femur. Lapparent de Broin and Verner in 1998 discovered few turtle taxa of fresh water and marine turtle. During our expedition to the west of Dakhla Oasis we recorded the first discovery of the gigantic marine turtle of Egypt from this site (figs 5C and 5D), in addition to some other vertebrate remnants such as shark teeth, turtle bones, marine reptiles (mosasaurs and plesiosaurs) teeth and scattered vertebrae.

Taphonomic features

The bones of vertebrate fossils that are collected form Abu Minqar area heavily abraded such as the marine turtle limbs, dinosaur hind limb element and the mosasourbones. The extended lateral or medial processes of the limb hones and the ends of the bone elements are broken of highly abraded, which indicates that these fossils are transported for long distances by high currents on the surface of the ocean after death of the animal.

Most of the vertebrate fossils are found as separated elements and no elements are found closely to each other's, which proof the deposition in high energy currents in inner neritic to littoral environment (Tantawy et al. 2001). The turtle shells are found as highly abraded separated small pieces. The vertebrate bones are embedded in A- zone (Bossenker, 2011), which may indicate a low rate of sedimentation.

Inspite of the high abrasion and fragmentation of the vertebrate fossils, their bones have very well-preserved textures with deformations or re-alteration with other elements. The bio-erosion evidences are not yet observed in the vertebrate fossils of this site.

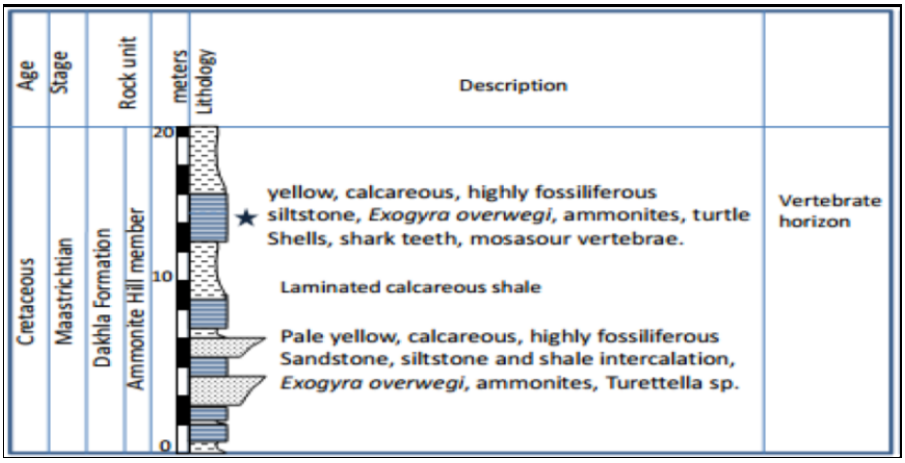

Fig. 4: Stratigraphic section of the Ammonite Hill member at Abu Minqar area.

Fig. 5: Vertebrate fossils locality of Abu Minqar area. A) General view of Dakhla Formation near Abu Minqar area. B) Ammonite Hill member of Dakhla Formation at Abu Minqar area. C) Limb element of marine turtle, scale 20 cm. D) humerus of giant marine turtle, scale 30 cm.

Bahariya Oasis vertebrate bearing site

Field investigation

The Cenomanian vertebrate fossils of Bahariya Oasis are collected from the association facies 1 of Catuneanu et al. (2006) of the base of Bahariya Formation at Gebel El Dist, north Bahariya Oasis (Stromer, 1931; Smith et al. 2001).

This faciesis formed of grayish white cross bedded sandstone topped by siltstone and dark gray mudstone, containing fragmented petrified wood, leaf prints and dinosaur, turtle, fish and crocodioformis remnants, (figs. 6, 7A, 7B and 7C).

Gebel El Harra near Harra village east Bawiety (capital of the Bahariya Oasis) is one the promised site of bearing Cenomanian dinosaur remnants of Baharyia Oasis.

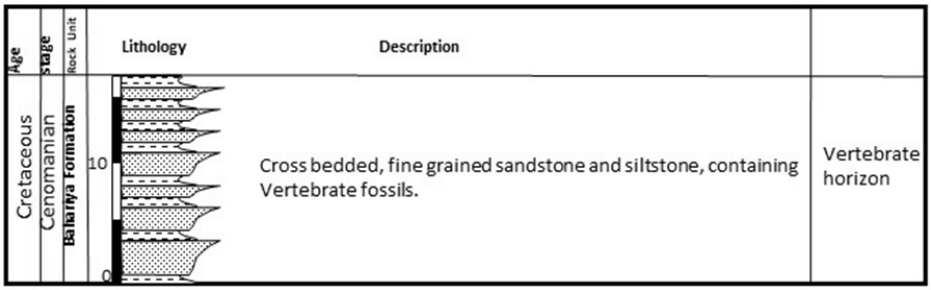

Fig. 6: Stratigraphic section of the lower part of Bahariya Formation, Bahariya Oasis.

Fossil content

The Bahariya Oasis is the type locality of the Cenomanian dinosaurs of Egypt. Ernst Stromer(1934) discovered very important dinosaur remnants from Bahariya Formation of Bahariya Oasis. These fossils were represented by four dinosaur genera: Therapod *Carcharodontosaurus* and *Bahariasaurus* and Sauropod dinosaurs (*Spinosaurs* and *Aegyptosaurus*) and some fishbones. The most published data on these dinosaur fossils were based on the data published by Stromer (1931, 1934). Some dinosaur bones are observed in the area during the present work, (figs. 7D, 7E and 7F).

Smith et al. (2001) discovered partial skeleton of the large Sauropod dinosaur *Paralatitine stroemeri* from the tidal flat and tidal channels facies of Bahariya Formation of Bahariya Oasis.

These fossils are associated with other vertebrate fossils, including fish, crocodyiloforms, squamates, Plesiosaurs, and turtles, (Stromer, 1936, Smith et al. 2006 and Lammana et al 2004). Unfortunately, these fossils were destroyed during an allied bombing raid in Munich during the Second World War.

Taphonomic features

Most of the collected vertebrate fossils of Bahariya Formation are scattered and separated elements, especially of dinosaurs. These elements are represented by separated teeth, partial jaws, partial and occasional complete fore and hind limbs and vertebrae lacking the processes. These bones are slightly abraded which indicates that they might have been transported very short distance with low energy currents. The bio-erosion deformations are observed in the big bones of dinosaurs. Some bones are highly affected by the high levels of underground waters and deformation by gypsum alterations.

Taphonomic controlling factors

Thetaphonomic assessment of the vertebrate fossils depends mainly on the natural conditions, such as: the types of the bearing sediments of the vertebrate fossils, rate of sedimentation, rate of transportation, bio-erosion and diagenetic events (Table 1). The most effective conditions are discussed as follows:

a- The types of the bearing sediments of the vertebrate fossils played an important role of the preservation of the fossils. The sand considered the best bearing sediments of the vertebrate fossils because they are not easily affected by the chemical weathering such as Eh or pH or by the physical weathering such as eolian and aquatic types, and also it has less effect by the high loading of the overburden.

The sandstone vertebrate fossils horizons are represented in Bahariya Oasis and Abu Minqar area. The mudstone sediment type which contains minerals that easily affected by the chemical weathering are bad for the fossilization and preservation of fossils, which the alteration processes form mineral to the other by the chemical weathering cause deformation of the fossils as in Quseir Formation of Kharga Oasis. The cracking attribution of the mud caused damaging and fragmenting of the fossils. The glauconitic variegated mudstones of Quseir Formation, Kharga site are high compacted sediments, consequently the bone embedded in these layers are highly cracked and deformed and occasionally squeezed by the overburden loading.

The rate of sedimentation is an essential controlling factor on the preservation of vertebrate fossils. The high rate of sedimentation gives big chances of rapid burying of the carcasses of the animal after death and deposition in B- interval (in the middle part of the layer). This mode of deposition of the carcasses give well preserved states of the fossils, and high degree of articulation turtle fossils in Quseir Formation of Kharga Oasis with taking in the consideration the effect of the other taphonomic controlling factors. The high rate of sedimentation is also represented in Bahariya Oasis, where the well-preserved vertebrate fossils elements in the cross bedded sandstone horizon. Inspite of the well-preserved vertebrate fossils of Bahariya Formation, they are found as disarticulated elements, especially of dinosaur, because of transportation factors by currents into swamps with rapid burying, where the high rate of sedimentation. While the low rate of sedimentation caused a high concentration of the bones on the top of the bearing layers (A- interval), (Boessencker et al. 2011), resulting disarticulation and scattering of the elements of the skeletons, in addition to the increasing of the

exposure times of the skeletons on the sea floor and resulted in poor preservation and disarticulation of the fossils as in Abu Minqar area.

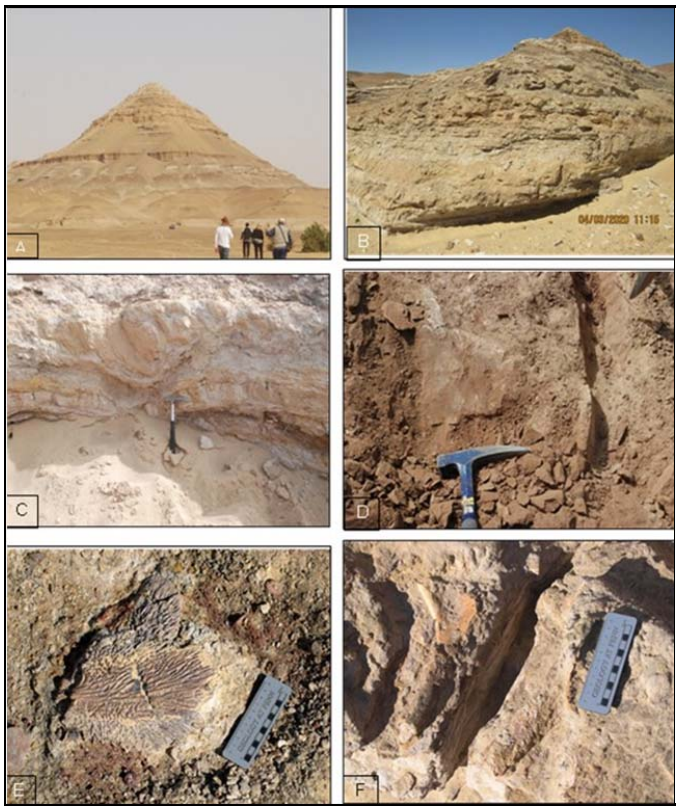

Fig. 7: The vertebrate fossils locality of Bahariya Oasis, A) General view of Gebel El Dist, north Bahariya Oasis, B) the lower part of Bahariya Formation, containing the horizon of vertebrate fossils.C) The convoluted, cross bedded sandstone and siltstone, the horizon of vertebrate fossils. D) big dinosaur bones embedded in sandstone layer. E) *Mawsonia,* fishbone fragment, F) fragmentary dinosaur bone.

b- **The rate of transportation** of the fossils depends on the energy currents and the weight of the bones. The high energy of currents with mixture of coarse and fine-grained sediments transported the fossils for long distance, except the heavy bones which are transported for short distances as the fore and hind limbs, causing high degree of abrasion and fragmentation.

The high energy currents cause high abrasion, dispersing and fragmentation of the vertebrate fossils. The heavy elements such as fore and hind limbs had strong friction with the coarse sediments, causing damaging of their heads and reached the basin without or with highly abraded heads. The small elements of the skeletons were moved by the high currents with little friction with the sediments of the substrate, so that they reached the basin with little degree of abrasion and semi complete elements. The deposition in high energy currents is represented in the highly fossiliferous sandstone and siltstone horizon of Ammonite Hill member at Abu Minqar area, where highly abrasion and separation of the elements of the vertebrate fossils, especially the marine turtles and Mosasour fossils.

Contrarily, the low energy currents with fine grained sediments transported the elements for short distances, resulting low degree of abrasion and fragmentation. The separation of the elements of the main skeleton are depend on their weight and shape, the light and blunt elements such as scapulae, lower jaws, ribs and pelvic bones were easily separated from the main skeleton and transported for long distances. The teeth were very easily separated from the jaws and transported longer distances than any other elements. The fluvial channels with high energy currents and low rate of sedimentation made passive accumulations of the vertebrate fossils (Lyman 1994), at the mouth of the channels. The low rates of transportation of the vertebrate fossils are reported in the lower part of Bahariya Formation in Bahariya Oasis, where the low energy fluvial current with fine grained sediments and also in Qusier Formation of Kharga Oasis, where the energy stream currents in the estuarine deposits. The low energy currents moved the elements of the main skeleton for short distances, so that, the elements of main skeleton might be yielded very close to each other or scattered in small area with slightly abraded state.

Bio-erosion

The bio-erosion is the penetration of the surface of the hard substrates of rocks, woods and bones by some animals, plants and microbes (Bromley, 1992). The bio-erosion on the Cretaceous vertebrate fossils of the studied sites is observed in Bahariya and Kharga sites. The bio-erosion traces are represented by boring traces, predator biting and grazing.

Boring traces

The boring trace fossils are the penetration of the surface of hard substrates such as bones, woods or rocks by some animals such as animal, plant or microbes (Bromely, 1992).

The boring traces are observed only in Bahariya Formation, Bahariya Oasis on some isolated dinosaur bones (Fig. 8A). It is circular in cross section boring on the surface of the bones. These trace fossils indicate nearshore or deltaic settings.

The predator biting

The scavenging on the turtle carcasses by some associated animals such as crocodiles are observed on the turtle carapaces of Quseir Formation, south Kharga Oasis, (Fig.8 B). This scavenging might be one of the causative factors of the fragmentation and scattering of the turtle's shells of the area.

Grazing

Sub-parallel and curved irregular scratches and pits marks on the surface of carapaces and plastrons of the turtles of Quseir Formation, Kharga Oasis, (Fig.8 C). These traces may be produced by the work of gnawing of some echinoids, fish or crabs (Bromely, 1975). The presence of these trace fossils of the south of Kharga main that this area recorded a period of invasion of the sea with non-deposition of sediment and exposure of turtle's carapaces and plastrons before burial. The grazing trace fossils indicate for the proximal shallow euphotic zone.

Diagenetic events

Some diagenetic events have been occurred on the vertebrate fossils on the study areas caused deformation of the shape and textures of the vertebrate bones as follows:

Re-permineralizain of the fossilized bones

Moreover, many elements of vertebrate fossils have deformed structures by re-permineralization by gypsum crystals in shale layers due to the high concentration of sulfur which may come from the decaying of the organic matters as plants (Bown and Kraus, 1988), as in Quseir Formation in Kharga Oasis (Fig. 8 D).

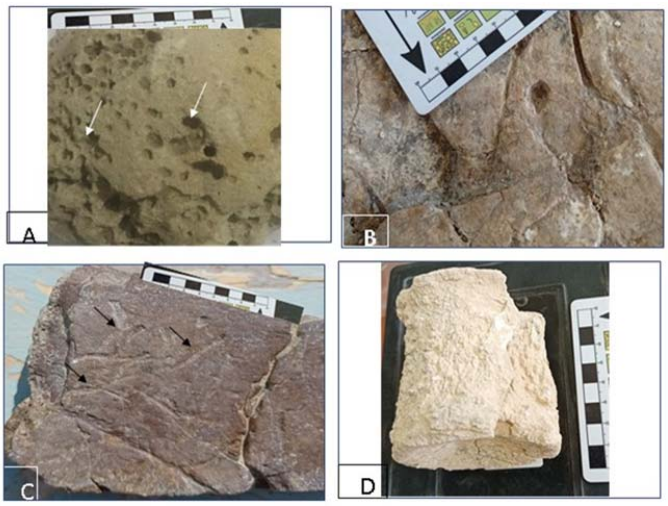

Fig. 8: trace fossils and some diagenetic events in the vertebrate fossils of the study areas, A) Boring traces in the dinosaur bones of Bahariya Formation, Bahariya Oasis, B) predator biting trace in the turtle bones of Quseir Formation, Kharga Oasis, C) Grazing trace fossils in the turtle bone of Quseir Formation, Kharga Oasis, D) Deformation by the re-permineralization of reptile vertebrae.

Taphonomic conditions and assessment of the Late Cretaceous vertebrates

Table 1; Summary of the taphonomic controlling factor and the taphonomic conditions of Kharga Oasis, Abu Minqar area, Baharyia Oasis.

Age	Formation	Fossil content	Paleoenvironment	Taphonomic controlling factor			Taphonomy data			
				Rate of sedimentation	Rate of Transportation	Sediment type	Articulation	Fragmentation	Abrasion	Bir-erosion
Maastrichtian	Dakhla	Marine reptiles, turtles, shark teeth, fishbones	Nearshore, lagoonal	low	high	Sandstone siltstone	4	3	4	Not yet recorded
Campanian	Quseir	Dinosaurs, crocodiles, turtles, fishbones	Intertidal, supratidal marshes and estuarine	High	low	Compacted mudstone	Turt. 1 Dino., croc. 4	2-3	1	Grazing traces
Cenomanian	Bahariya	Dinosaurs, turtles, fishbones	Subtidal and fluvial facies	High	Low	sandstone	4	3	3	Boring traces

CONCLUSION AND RECOMMENDATIONS

The Western Desert contains attractive Cretaceous terrestrial and marine reptiles and other vertebrate areas, among them the three selected representative vertebrate bearing sites in Kharga, Bahariya oases and Abu Minqar area. Based on the integration of the stratigraphic data and the data of the field taphonomic investigation of the vertebrate bearing sites, the following concluded point scan is summarized.

The vertebrate fossils of Kharga Oasis are yielded in intertidal to supratidal, marshes and estuarine compacted variegated shale of Campanian Qusier Formation with low rate of transportation and high rate of sedimentation. These fossils are articulated, slightly fragmented and slightly abraded. Grazing and biting trace fossils are recorded in the turtle bone fossils.

The vertebrate fossils of Abu Minqar area are yielded in nearshore and lagoonal fossiliferous sandstone and siltstone of the Maastrichtian Ammonite Hill member (Dakhla Formation) with high rate of transportation and low rate of sedimentation. These fossils represented as scattered elements, fragmented and highly abraded.

The vertebrate fossils of Bahariya Oasis are yielded in subtidal and fluvial cross bedded sandstone with low rate of transportation and high rate of sedimentation. These fossils occur as separated elements, slightly fragmented and slightly abraded. The boring trace fossils are recorded on dinosaur bones of the Bahariya Formation sequence.

The vertebrate fossils in the sediments of Bahariya and Kharga oases are more preserved than the fossils in the sediments of Abu Minqar area and lessabraded. These are most probably due to their occurrencein the lower energy currents with higher rate of sedimentation than those in Abu Minqar area. Furthermore, it was observed that the vertebrate bearing horizons of Kharga and Bahariya oases are reported in lower topographic levels (near the oases floor) and consequently, are highly affected by erosion by wind and groundwater actions. Also, these horizons are affected by the random land reclamations and illegal ecotourism activities. On the other side, the vertebrate bearing horizons in Abu Minqar area are located quite higher topographic level and therefore, they occur in occur in in better preservation state, where the fossils are far away from such negative impacts of the human activities. For these reasons, it is highly recommended to protect these vertebrate fossils treasures from the negative impact haphazard human activities.

Recommendations

The Late Cretaceous vertebrate fossils are represented one of the most important natural heritage sites of Egypt and even in the world. They could be of the source of the national income of Egypt by the ecotourism activities, in addition to its great scientific importance. Inspite of some of them have been declared as protected area, they are in urgent need of more protection and preservation in a scientific way that maintains the sustainable development and benefits from them by increasing the national income of Egypt. Therefore, we introduce some recommendations:

1- Introduce data and management plan of each site to the decision maker to protect it.
2- Good environmental awareness of the local communities to know the scientific and economic importance of these sites
3- Firmlypreventing of the random leveling for the ground by some local.
4- Detecting and marking the sites by signs explain the importance of it and give warning of infringing up on it.
5- A distinct research Plan for each site to increase the scientific importance for each site.
6- Providing some jobs of some local communities for guarding the site.

ACKNOWLEDGMENTS

The author deeply thanks prof. Dr. Mohammed Ibrahim El Anbaawy, Cairo University for his accurate review and his very important advices to complete this work. Very deep thanks to prof. Dr. Gouda Ismail Abdel-Gawad, Beni-Suif University for his accurate review of the article. Very deep thanks forDr. Mohammed AbdelGawad, Cairo University, for his great helping during the sending of the article to the journal. We thank very much Geologist Mohammed Kamel, New Valley University for his great efforts in the Field work. Very deep thanks for Mr. Ahmed Farrag, the guide of Kharga desert for his all efforts in the field works.

REFERENCES

AbdelGawad, M. K, Kassab, W, and Abu El-Kheir G. A. (2019): Reviewing of the Testudenes occurrence in the Late Cretaceous from South Western Desert, Egypt. 21.EGU2019-1671, Europian Geoscience Union General Assembly.

Abu El-Kheir, G. A, AbdelGawad, M. K, and Kassab W. G. (2018): A new vertebrate locality of Maastrichtian successions of the Dakhla Basin, Western Desert, Egypt. The 78th Annual Meeting of the society of Vertebrate Paleontology. October 2018. Journal of Vertebrate Paleontology, Program and Abstracts, 2108, 62 p.

Awad, G. H. and Abed, M. (1969): Biostratigraphical zoning of the lower Tertiary in the Dakhla Oasis. Geological Survey, UAR 47, 63 pp.

Barthel, k. W. and Herrmann-Degen, w. (1981): Late Cretaceous and Early Tertiary stratigraphy in the Great Sand Sea and its SE margins (Farafra and Dakhla Oases), SW Desert, Egypt. Mitt.bayer. Staatsslg. Paliiont.hist. Geol., 21, 141-1 82.

Boessenecker w. R., Schmitt G. J., Custer G. S. (2011): Comparative taphonomy and taphofacies analysis of marine vertebrates of the Neogene Purisima Formation, Central Carolina, M. Sc. Montana state University, Bozeman, Montana.

Bown, T. M. and Kraus M. J. (1988): Geology and paleoenvironment of the Oligocene Jebel Qatrani Formation and adjacent rocks, Fayum Depression, Egypt: U.S. Geological Survey Professional Paper, 1452, 1-60.

Bromley, R. G., (1975): Comparative analysis of fossil and recent echinoid bioerosion: Palaeontology, 18, 725-739.

Brand, L. R., Goodwin, H. T., Ambrose, P. D., Buchheim, H. P., (2000): Taphonomy of turtles in the Middle Eocene Bridger Formation, SW Wyoming: Palaeogeography, Palaeoclimatology, Palaeoecology, 162, 171-189.

Bromley, R. G. (1992):Bioerosion: eating rocks for fun and profit, p. 121-129. In:
Maples, C. G.and West, R. R. (eds.), Trace Fossils. Short Course in Paleontology 5.

Catuneanu O, Khalifa M. A, Wanas H. A (2006): Sequence stratigraphy of the lower Cenomanian

Bahariya Formation, Bahariya Oasis, Western Desert, Egypt,Sedimentary Geology (190) 121- 137.

El Hedeny, M., Kassab, W., Rashwan, M. Abu El-Kheir, G. and AbdelGawad, M. (2020): Bivalve borings in Maastrichtian fossil Nypafruits: Dakhla Formation, Bir Abu Minqar, SouthWestern Desert, Egypt, Ichnos, DOI: 10.1080/10420940.2020.1784158

Ghobrial, M. G. (1967): The structural geology of Kharga Oasis: Geol.Surv.Egypt, Paper no.43, 39p.

Hendriks, F., Luger, P., Kallenbach, H., and Schroeder, J. H. (1984): Stratigraphical and sedimentological framework of the Kharga-Sinn El-Kaddab Stretch (Western and southern part of the upper Nile Basin), western desert, Egypt. Berl. Geowiss. Abh.A 50, 117e 151.

Hermina, M. (1990): The surroundings of Kharga, Dakhla, and FarafraOases. In: Said, R. (Ed.), the Geology of Egypt. AA Balkema, Rotterdam, 259-292.

Khalifa, M. A., Abu El-Hassan, M. M. (1993): Lithofacies, diagenesis, cyclicity and depositional environment of the Upper Cenomanian El-Heiz Formation, Bahariya Oasis, Western Desert, Egypt. J. Afr. Earth Sci. 17, 555–570.

Klitzsch, E. and Schandelmeir, H. (1990): South western desert. In: Said, R. (Ed.), The Geology of Egypt. Balkema, Rotterdam, Netherlands.

Lamanna, M. C., Smith, J. B., Attia, Y.S., Dodson, P. (2004): From dinosaurs to dyrosaurids(Crocodyliformes): Removal of the post-Cenomanian (Late Cretaceous) record of Ornithischia from Africa. J. Vertebr. Paleontol. 24, 764-768.

Mahmoud, M., (2003): Palynology and palaeoenvironment of the Quseir Formation (Campanian) from central Egypt. J. Afr. Earth Sci., 36, 135e148.

Lapparent de Broin, F., Werner, C. (1998): New late Cretaceous turtles from the western desert, Egypt. Ann. Paleontologie 84, 131-214.

Lyman, R. L. (1994): Vertebrate Taphonomy. Cambridge University Press, Cambridge.

Rauhut, O. W. M. and Werner, C. (1997): First record of a Maastrichtian sauropod dinosaur from Egypt. Palaeontol. Afr. 34, 63–67 (1997).

Said, R., (1962): The Geology of Egypt Elsevier, Amsterdam, 377 pp.

Sallam H. M. O'Connor P. M, Kora M., Sertich J. W. J., Seiffert R. E, Faris M., Ouda K, El-Dawoudi I., Saber S. and El-Sayed S. (2016): Vertebrate paleontological exploration of the Upper Cretaceous succession in the Dakhla and Kharga Oases, Western Desert, Egypt, J. Afr Earth Sci., 117, 223-234.

Smith B. J, Lamanna C. K., Lacovara K. J., Dolson P. Smith R. J., Poole C. J, Giegengack R, Attia Y. (2001): Agiantsauropod Dinosaur from an Upper Cretaceous Mangrove deposit in Egypt. Science 292.

Smith, J. B., and Lamanna, M. C. (2006): An abelisaurid from the Late Cretaceous of Egypt: implications for Theropod biogeography. Naturwissenschaften 93, 242-245.

Stromer, E. (1931): Ergebnisse der Forschungsreisen Prof. E. Stromer in den Wüsten Ägyptens. II. Wirbeltierreste der Baharje−Stufe (unterstes Cenoman). 10. Ein Skelett−Rest Carcharodontosaurusnovgen. Abhandlungen der Bayerischen Akademie der Wissenschaften, Mathematisch−Naturwissenschaftliche Abteilung, Neue Folge, 9: 1–23.

Stroemer, E. (1934): Ergebnisse der Forschungsreisen Prof. E. Stromers in den Wüsten Ägyptens. II. Wirbeltier−Reste der Baharije−Stufe (unterstes Cenoman). 13. Dinosauria. Abhandlungen der Bayerischen Akademie der Wissenschaften Mathematisch− Naturwissenschaftliche Abteilung, Neue Folge 22: 1–79.

Tantawy, A. A., Keller, G., Adatte, T., Stinnesbeck, W., Kassab, A. and Schulte, P. (2001): Maastrichtian to Paleocene depositional environment of the Dakhla Formation, Western Desert, Egypt: sedimentology, mineralogy, and integrated micro- and macrofossil biostratigraphies. Cretac. Res. 22, 795-827.

Youssef, M. I. (1957): Upper Cretaceous Rocks in Kosseir Area. Bull. Inst. Desert Egypt. 7, 35-54.

ظروف ما بعد النفوق وتقييم مواقع الحفريات الفقارية خلال العصر الكريتاسي العلوي بالصحراء الغربية بمصر

جبيلي عبد المقصود ابو الخير

كلية العلوم–قسم الجيولوجيا– جامعة الوادي الجديد

الخلاصة

تتناول الدراسة العوامل الطبيعية التي تتحكم في ظروف ما بعد النفوق لمواقع الحفريات الفقارية بالصحراء الغربية خلال العصر الكريتاسي بالصحراء الغربية بمصر وتقيم تلك المواقع من حيث المحتوي الحفري لها. تتمثل تلك الموقع في ثلاثة مناطق رئيسية وهي واحة الخارجة، منطقة أبومنقار– غرب واحة الداخلة والواحات البحرية.

تتركز مواقع الحفريات الفقارية بواحة الخارجة بمكون القصير (الفترة المتاخرة من العصر الكريتاسي العلوي) حيث تم تسجيل عدة مواقع بتلك المنطقة تحتوي علي حفائر لانواع من الديناصورات والسلاحف والتماسيح وأسنان القرش وعظام لبعض الاسماك والتي ترسبت في طبقات الطفلة ذات التيارات المائية الضعيفة ومستوي ترسيب عالي ولتي وجدت في حالة حفظ شبه جيدة. أما منطقة أبومنقار غرب واحة الداخلة فتتركز الحفريات الفقارية بتلك المنطقة بعضو تل الامونيت بالجزء السفي لمكون الداخلة (نهاية العصر الكريتاسي العلوي) والتي تحتوي علي عظام لبعض الديناصورات، عظام لبعض السلاحف البحرية العملاقة، عظام لبعض الزواحف البحرية والاسماك وأسنان القرش والتي ترسيبت داخل طبقات الحجر الرملي ذات التيارات القوية ومتسوي الترسيب العالي حيث وجدت في حالة حفظ سئية.

بالسبة لمواقع الحفريات الفقارية بمنطقة الواحات البحرية فتتركز تلك الحفريات بمكون البحرية بعدة مناطق من أهمها منطقة جبل الدست شمال الواحات البحرية حيث جمع العديد من الحفريات الفقارية بتلك المنطقة من أهمها الديناصورات بانواعها المختلفة بعض السلاحف والتماسيح وبعض عظام الاسماك والتي ترسبت في طبقات الحجر الرملي ذات التيارات الضعيفة ومستوي الترسيب الحالي، وقد جدت في حالة حفظ جيدة .

كان للتأكلات البيولوجية أو أثار الكائنات الحية دور ثانوي في حدوث بعض التغيرات علي العظام داخل الطبقات من حيث حدوث تشوهات بالاسطح الخارجية لها والتي تمت ملاحظتها بمواقع الحفريات بواحة الخارجة مثل أثار رعي وتغذية بعض الكائنات مثل الاسماك أو الكابوريا وكذلك أثارالعض لبعض أسنات الكائنات الكبيرة مثل التماسيح نخر أسطح العظام والتي تسمي التريدو والتي تم رصدها بمواقع الحفريات الفقارية بجبل الدست بالواحات البحرية. حدثت هناك بعض تغيرات ما بعد الترسيب علي تلك العظام مثل حدوث استبدالات المعادن بالجبس وتشوهها وأيضا حدوث طلاء لبعض أسطح العظام بالحديد أو المنجنيز المتركزة بالمستويات العالية من المياه الجوفية .

تمثل مواقع الحفريات الفقارية للعصر الكريتاسي العلوي بالصحراء الغربية بمصر واحدة من أهم مواقع حفائر الزواحف القديمة النادرة جداً علي مستوي قارة أفريقيا والتي من خلال تكثيف البحث علي تلك الحفريات والعمل علي حمايتها سوف تزيد من المعرفة لهذه القارة المفقودة